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Some Questions and Answers About the Mountain Pine Beetle (Dendroctonus ponderosae) and the Cooperative Control Research Program.

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RGC, 9/6/68

Some Questions and Answers About the Mountain Pine Beetle (Dendroctonus ponderosae) and the Cooperative Control Research Program.

1. How do the beetles attack and kill a tree?

The initial attacks of the mountain pine beetles occur within a few feet of the base of the tree. An adult female beetle, which has emerged from a previously infested brood tree, initiates the attack by boring through the bark to the phloem or inner bark between the bark and sapwood, where she constructs her egg gallery. After she has been feeding on fresh phloem for several hours, she produces an odor or "pheromone". This odor attracts large numbers of other beetles, both female and male, to the tree resulting in a mass attack by the females boring their egg galleries. A mass attack is essential for the beetles' success in killing the tree because if only a few attack they are usually "pitched out" or drowned by the heavy flow of resin in the entrance galleries.

A healthy tree will have a resin pressure somewhere between 80 to 120 p.s.i. The first attacks may be easily recognized by the reddish brown pitch tubes which are formed at the entrance holes of the attacking beetles. If the tree has a high resin pressure, then the size of the pitch tubes will be large and often the beetles will be "pitched out". However, if the first beetle is successful in luring a large number of other beetles to attack the tree, a reaction occurs which is comparable to opening all the water faucets in a house: the resin pressure drops which lowers the tree's resistance to the beetles. Once the resin pressure is reduced, the successive attacks may not result in visible pitch tubes, but boring dust will be seen in the crevices of the bark and scattered around the base. After the initial attacks have occupied the base of the tree, the successive attacks will advance upward until the lower 20 to 30 feet of the bole may be invaded by hundreds of beetles.

Following the mountain pine beetles, other secondary bark beetles frequently invade the tree, e.g., the red turpentine beetle near the ground line, and the Ips engraver in the upper part of the bole.

Shortly after the female beetles enter the tree, they attract male beetles into the "nuptial chamber" near the entrance hole where copulation occurs. In the case of the mountain pine beetle, only one male beetle mates with one female--that is, they are "monogamous" insects. (Some other species of beetles are "polygamous", i.e., one male may mate with several females.)

After copulation the female continues to construct her egg gallery in the phloem in a generally upward direction or parallel to the bole of the tree. (Certain other species construct their egg galleries at right angles to the bole.) Egg laying will commence within 3 or 4 days following the first mating. The female deposits about 80 to 100 eggs in small niches along the sides of the gallery. As the egg gallery is extended, the female kicks the "frass" (mixture of boring dust and feces) behind her, pushing it down the gallery to the male. She then moves forward and continues to work on the upper end of the gallery. If the male is close to the entry hole, he will push the frass to the outside of

the tree. After the boring has advanced some distance from the entry hole, the frass is compacted in the gallery by the male. The beetles usually keep 6 to 8 inches of gallery at the upper end free of frass.

The eggs hatch in a few days into larvae, or small grubs, which feed through the phloem, constructing small tunnels generally at right angles to the egg gallery. These larval "mines" sever the phloem tissue which transmits food from the tree crown to the roots.

As the female bores her entrance hole and egg galleries, she carries the spores of a fungus which once covered her pupal chamber. The fungus quickly grows through the outer sapwood to block the water-nutrient conducting tissues. This reduces the flow of pitch, makes the construction of galleries much easier, prevents "drowning" of the larvae, and thereby enables the beetles to make a "successful" attack.

With the water-nutrient pipeline from roots to crown plugged by the fungus and the food pipeline from needles to roots severed by the beetle, the tree literally dies of thirst and starvation within a few weeks.

After a successful attack, discoloration of the tree crown will slowly begin, depending upon the amount of moisture available for the tree. The needles fade through successive stages of yellow, red, sorrel, and finally brown before they fall.

2. How does the mountain pine beetle rank with other insects in terms of damage caused to forests?

No overall current survey data for the Northern Rocky Mt. Region is available. Several defoliators (tussock moth, bud worm, case bearer) have caused some mortality and severe growth loss in many species other than pine. However, bark beetles are historically the worst out-right killers of mature trees of several species. The mountain pine beetle in white pine has probably caused more value loss than any other beetle over the last 50 years, although severe losses have also been caused by the Englemann spruce beetle, the Douglas fir beetle, and the western pine beetle in ponderosa pine.

A 1967 estimate (by R. G. Cox, chairman of the industry coordinating committee for this project) indicated the mortality in white pine from the mountain pine beetle was at least 200,000,000 board feet annually over the last 10 to 15 years. This estimate is probably conservative because it was based on an 1.3% overall average annual mortality times the total estimated remaining volume of white pine (15 billion board feet) in the Region. Actual annual mortality of white pine has been averaging as high as 4% in many northern Idaho forests, with some stands running as high as 25% annually at the last peak of the epidemic in about 1964.

3. What is the life cycle of the beetle?

The mountain pine beetle (Dendroctonus ponderosae) passes through egg, larval, pupal, and adult stages during its life cycle under the bark of the tree. The tiny pearly-white eggs hatch into yellowish-white, legless grubs or larvae. After passing through three stages of growth and development, called instars, these larvae transform into pupae and then into adults. Newly formed adults are yellowish brown at first but turn black at maturity. These short-legged, stout, cylindrical creatures, about 3/16 inch long, can fly readily to new host trees. The insects overwinter in the brood tree as old (parent) adults, eggs, larvae, and new (callow) adults.

Emergence the next year is largely controlled by weather conditions, with the first beetles appearing from their specially constructed emergence holes when daytime temperatures reach 70° to 80° for a week or two. Generally, there are two major peaks of emergence--one in mid or late June and another in mid July to mid August. If temperatures remain favorable, there may be a third, but usually lower, peak of emergence in September.

New attacks are made immediately after emergence. The resulting broods develop to new adults, mature larvae, or small larvae before cold weather, depending on time of egg hatching. Some eggs laid during a September attack may not hatch until next spring.

4. When and how did this current epidemic start?

The mountain pine beetle is a native pest of several pine species which has periodically caused severe damage to merchantable timber stands since the beginning of recorded forest history in the West. The pest has plagued man ever since he first began to develop a western lumber industry in the early 1900's. Numerous outbreaks of this beetle have been recorded. Many hundreds of millions of board feet of prime timber were lost in remote areas before modern logging transportation and equipment systems were developed.

The current outbreak, at least in northern Idaho, followed a series of wind and snow storms in the early 1950's which broke off and up-rooted thousands of trees scattered over many hundred thousand acres. Under normal forest conditions, the beetle is kept in check by its "natural enemies", i.e., other "predator" insects, diseases, and birds. However, this balance was upset by the sudden creation of a large volume of damaged and wind-thrown trees which have low resistance to beetle attack. The pest populations increased much faster than those of their natural enemies, resulting in a full-blown epidemic over a vast forest area.

In the Northern Rocky Mt. Region, three of the major commercially-important tree species were heavily attacked--white pine, Englemann spruce, and Douglas fir. Three separate species of bark beetles were involved, one for each tree species, but all belonged to the single genus, Dendroctonus.

Following the 1950 outbreak, a large-scale cooperative program was undertaken by federal, state and private agencies to survey the affected forest, pinpoint areas of heaviest damage, and set priorities for salvage operations. Thousands of miles of new roads were built into previously virgin and inaccessible stands. Many hundreds of millions of board feet of high-quality timber were salvaged. In spite of these efforts, a large volume of timber was lost as sawlogs because the dead trees had deteriorated to an un-utilizable condition by the time the loggers arrived.

The tree species most decimated by the beetle epidemic was Englemann spruce which was nearly "wiped out" in many areas in northern Idaho, western Montana, and Colorado.

The epidemic in Douglas fir generally subsided to an "endemic" or near-normal level after a few years, although outbreaks in smaller "hot-spot" areas still occur.

The epidemic in white pine, the most valuable tree species affected, has continued at a fluctuating but generally high level. The last peak recorded in Potlatch Forests, Inc.'s Clearwater Tree Farm was about 1964, but infestation is still at a high level.

The reasons for this continued epidemic in white pine are numerous but not all clearly understood. For example, many of the white pine stands are of a mature age, but so are the other tree species not as heavily infested. Also, many of the white pines are severely infected with blister rust fungus which has reduced their general vigor, perhaps making them more vulnerable to beetle attack; however, the correlations between blister rust damage and incidence of beetle attacks have not been fully researched.

In any event, the seriousness of the mountain pine beetle epidemic in white pine has forced all forest managers--federal, state and private--to cut this tree species far heavier than originally prescribed under our sustained yield or even-flow management plans.

5. Why have past control efforts failed?

Theoretically, bark beetles could be controlled if all, or a sufficient number, of the "brood trees" (containing live insects) could be located and the broods destroyed before emergence. Many attempts to apply this theory have been made. While temporary success has been achieved on relatively small areas, there are few, if any, examples of long-term control over large areas. Not only has this approach been ineffective, it is also too costly.

There are many reasons for failure of past methods, the most important of which is the sheer physical difficulty of locating even 90% of the brood trees over a large area. Even though the crowns of infested trees gradually fade and eventually turn various shades of easily-seen yellow and red, this fading often

does not occur until the beetle brood has emerged and flown on to attack other trees. A freshly-attacked tree cannot be seen from the air by any presently known technique (although research is being done on using infra-red and heat-sensing devices which may prove applicable). A ground surveyor must get close enough to the newly-attacked trees to be able to see the pitch tubes and boring dust. This means that every white pine tree must be closely inspected, an impractical if not impossible task over large areas containing several hundred thousand trees.

Another problem in applying the direct control method is the need to treat each individual brood tree from the ground. Aerial sprays are ineffective because the beetles are protected under the bark. Each brood tree must be either saturated with a bark-penetrating fumigant-type insecticide, or felled and sprayed or burned. This is not only a costly procedure, it also destroys the natural predators under the bark which are helping to reduce beetle populations.

6. How does this new idea of using attractants differ from the old?

Instead of trying to find and treat each brood tree, the attractants (either natural or synthetic) are being used in an attempt to lure the beetles to preselected and accessible locations near existing roads or logging landings where the insects can be easily and safely destroyed.

7. Is the attractant actually an "odor"?

Yes, in the sense that it is detected by the beetle's sense of smell organs or "olfactory receptors" located in the antennae.

8. How is the odor produced and used by the beetles?

In the case of the mountain pine beetle, it is produced only by the female after she begins constructing her nuptial chamber in the inner bark. Field bioassays (tests with "olfactometers" or traps) indicate the maximum attractiveness is generated after about 18 hours of feeding.

As the nuptial chamber is bored, some of the host tissue is ingested by the beetle and passed through its intestinal tract, being excreted as fecal material. When the ingested phloem particles reach the beetle's "hindgut", a chemical reaction (not fully understood) takes place which produces the "pheromone" or the material having the attractive odor.

Small amounts of the attractant are found in the fecal pellets, but it is most concentrated in the hindgut. This attractant, though produced in extremely minute quantities, is highly potent to beetles. As the substance is secreted and passed in the fecal pellets, it volatizes and is dissipated into the air surrounding the tree, and is carried by wind currents through the forest. Other beetles

flying in the forest canopy detect the scent and follow it to the "marked" tree.

Although both sexes are drawn to the tree, only one male enters or remains in each nuptial chamber. When mating begins, the female stops producing the attractant.

9. Can the odor be smelled by humans?

Not in the minute amounts produced by the beetles, but it can be detected when concentrated by the chemists. Some of the synthetic materials also have a distinctive odor.

10. If the synthetic attractants prove practicable, how will they be used to control the beetles?

First, we are not yet sure we can actually "control" the beetles. Our goal, of course, is to manipulate the beetle population in sufficient numbers to accomplish a significant reduction of tree mortality. We had hoped to demonstrate this by the end of this summer, but the early fall rains have suppressed beetle flights to that we could not complete all of our planned tests. Several techniques have already been tested, but more refinement is needed.

One research instrument used for attracting and capturing beetles is the "olfactometer" or field trap. These have proven highly effective in testing the relative attractive power of the various compounds. However, they are probably too cumbersome and expensive for large-scale control efforts because several hundred (we don't yet know how many) attraction stations scattered over a large area will probably be needed.

Another effective technique for attracting beetles is the use of "trap trees". These have been prepared in various ways. The most effective has been to select a fairly large, vigorous white pine, weaken it by hacking it around the base, spraying it with a tree-killing chemical, and then "baiting" it by attaching a small disseminator of the attractive mixture on the bark. Flying beetles are attracted to the tree in large numbers and are induced to make a "mass attack". The main disadvantage of this method is that the bait tree is killed, although it may be salvaged. A more acceptable method would avoid sacrificing a large number of bait trees.

Several ideas are now under study and will be tested as soon as adequate beetle flights occur. One is to bait undamaged trees with a combination of trans-verbenol and alpha-pinene, which has proven highly attractive in the olfactometers as well as on test trap trees. The lower boles of these bait trees could then be sprayed with a quick-acting insecticide to protect them from mass attack. However, the effect of such a method on the predator insects, which are often attracted too, must be thoroughly studied.

Another idea is to develop a different type of mechanical or non-

mechanical trap, using the synthetics to lure the beetles. Electronic devices for destroying the attracted beetles have been considered, but the problem of providing a practicable portable power source for the many remote locations must be solved.

The chief difficulty in testing control techniques arises from the flight habits of the beetles. The periods of peak emergence, flight and attack are infrequent and sporadic--usually not more than one or two during the summer, dependent on rather specific weather conditions. Hence, there are actually only a few days between early June and late August or early September when enough beetles are flying to adequately test attraction and trapping techniques on a "control" basis.

If a break in this unseasonably wet, cool weather occurs before fall, we may yet be able to complete our tests. If not, we will plan to have various apparatus installed and ready to test next spring to catch the first peak beetle emergence which usually occurs between mid-June and early July.

11. What are the facts about the term "sex attractant" which has been given so much publicity by other researchers in this field?

"Sex" is, of course, a popular and eye-catching word. The term "sex attractant" has been used by some of the bark beetle researchers and their publicists to dramatize and attract attention to their work. With respect to the bark beetles, the term "sex attractant" is considered by some authorities to not be scientifically correct. Some insects do produce a true sex attractant--which means an odor or other mechanism produced by one sex of the insect (either male or female) which entices and excites only the opposite sex. Examples of familiar insects where the female produces an attractant are the cockroach, honey bee, and certain moths. Examples of a male-produced attractant are the bumble bee, boll weevil and some fruit flies.

In the case of bark beetles, however, the pheromone (which may be produced by either sex, depending on the species) is attractive to both male and female, e.g., California pine engraver (male-produced), and the mountain pine beetle (female-produced). Hence, it is more correctly termed a "population aggregating pheromone", or an "assembling scent".

12. Where and how were the beetles obtained in the large numbers necessary for laboratory and chemical study?

This work was assigned principally to the field team at Headquarters, Idaho, where an old unused dairy barn was renovated to serve as a field laboratory. A portable bunkhouse was moved adjacent to the lab and converted to a beetle rearing facility.

The most productive method of collection is to "force rear" the beetles, which is accomplished as follows: Mass-attacked white pine "brood trees" are

located in the forest containing large numbers of beetles, preferably in the "new adult" stage which are ready to emerge in a short time. These trees are felled; the mass-attacked sections are cut into short bolts which are placed in a light-tight "rearing cage" where the temperature is maintained at about 70° Fahrenheit. A light is placed near the door of the cage, which attracts the beetles as they emerge. The beetles are then collected daily by being funneled into a container or by sweeping into a dustpan.

13. Since only the female beetles were wanted for the chemical analyses, how were the sexes separated?

This was the responsibility of the BTI group and was done mainly in California.

The sexes may be separated by several techniques, but the most efficient for the mountain pine beetle is on the basis of "stridulation", a sharp, chirping sound made only by the male. The laboratory technician can easily detect this chirp by placing each individual insect close to his ear. The females are placed in containers and stored in a refrigerator until needed. The males are destroyed unless desired for some other research.

The beetles captured in Idaho were placed in glass jars partially filled with moistened excelsior and air mailed to BTI's laboratory in Grass Valley, California. Interstate shipment of serious insect pests is permitted only when the recipient state already harbors the same species over large areas, which is the case with California where outbreaks of the mountain pine beetle have occurred in sugar and ponderosa pines.

14. How were the attractive materials obtained from the female beetles?

Captured females were inserted head first into preformed holes in fresh pine log sections and secured in place by covering the holes with one-inch squares of window screen. In a short time the females began to construct their galleries in the phloem or inner bark.

At the end of about 18 hours' feeding, the females were removed from beneath the bark of the log and the hindgut was carefully dissected from each female. The beetles are less than 3/16 of an inch long, and the hindguts represent only the very last portion of the insect's digestive tract; therefore, the dissections were performed under microscopes with tiny jeweler's forceps serving as "scalpels". The hindgut of an insect is analogous to the large intestine and rectum of a human.

The attractant material is highly volatile, which makes its capture and retention most difficult. Each hindgut, immediately after removal from the beetle, was frozen and stored at -158° F to prevent loss of the volatiles until sufficient numbers were available for airmailing to the chemists in Columbus, Ohio.

15. How did you prove these hindguts actually contained the attractive material?

By laboratory tests using a gas-liquid chromatograph (GLC), which is a complicated and extremely sensitive instrument capable of separating the various compounds of certain materials through a process of evaporation or volatilization. Simply explained, the instrument contains a coiled tube which may be heated to any desired temperature. The test material is introduced in one end of the tube and as it passes through the coil various compounds are vaporized, with the most volatile being driven off first. These materials are exhausted through the opposite end of the coil where they may be captured or tested directly for their beetle attractiveness. The simplest test is to place the beetles on a flat surface and expose them to the exhaust tube of the GLC. The beetles crawl toward the opening of the exhaust tube when the attractive material is being emitted but ignore the non-attractive materials.

The GLC has an automatic recording device which draws a line graph showing separate "peaks" for the various materials. The peak of the attractive material can be positively identified through replicated tests.

16. How many female hindguts were extracted to obtain the necessary quantity of natural material?

Because of the minute amount of attractant produced by each beetle, large numbers were required for the various studies.

During the winter of 1967-68 we concentrated our efforts on supplying the chemists at Battelle Memorial Institute with about 20,000 hindguts for the numerous analytical procedures necessary for identifying the exact chemical structure of the natural attractant compound, which is prerequisite to producing a synthetic. In their concluding effort to concentrate the natural material, the chemists extracted 5,000 hindguts which yielded only about 1/1000 of an ounce of the nearly-pure attractant.

17. How did you determine that alpha-pinene was the attractive compound in the resin?

Tests of trans-verbenol in August of 1967 showed that it had no attraction when used alone but that it was highly attractive when used with female-infested log sections. This strongly suggested that a "host" or tree factor was involved. Consequently our tests early this summer were concentrated on checking out this potential tree factor.

A mixture of raw pine resin and trans-verbenol proved to be highly attractive. Since alpha-pinene, which is readily obtainable as a commercial laboratory byproduct, was known to be a major component of pine resin, it was then tested with trans-verbenol. The results were immediately and spectacularly positive.

18. How did the chemists identify the chemical composition and structure of the attractive compounds?

First of all, the identification of compounds in the substance obtained from the beetles was made unusually difficult by the availability of only extremely small quantities of the concentrated natural attractant, as described in the answer to question 16. This requires a highly competent and experienced chemist who can identify molecules from quantities as small as 1/10,000 of an ounce.

Secondly, each fractionation, or refinement stage, must be bioassayed with live beetles to determine if the isolated material is still attractive.

The identification of the attractant compounds was a highly complicated technical procedure which is difficult to comprehend without an advanced knowledge of chemistry. No attempt will be made here to explain the details. Following is a greatly simplified description:

Several stages were involved, beginning with the gas liquid chromatograph previously mentioned. The GLC line graph provides clues on the identity of the compounds, i.e., the retention time before the peak occurs, the height and shape of the peak, and the cross-sectional area of the space under the peak. The desired candidate compound must be captured at the exhaust port of the GLC during only a few seconds of emission time.

Positive identification of the attractant was accomplished by first further purifying the 1/1000 ounce of semi-pure material through GLC and another process termed "thin layer chromatography". Then the chemical structure of the molecule (arrangement and bonding of the atoms) was determined by various analyses, including infrared, mass and nuclear magnetic resonance spectroscopy. Finally, the structural formula of trans-verbenol was assigned to the mountain pine beetle attractant. Trans-verbenol is a compound very close to alpha-pinene, a common constituent of pine pitch and turpentine.

19. How were the "man-made" compounds synthesized?

By another complicated chemical process. In the case of trans-verbenol, the beginning compound was freshly distilled alpha-pinene, which was oxidized, subjected to various chemical reactions, and purified by passing through a gas liquid chromatograph which separates the desired compound from the unwanted materials.

In the case of alpha-pinene, this compound is readily available as already indicated.

Technical reports prepared by Dr. Kinzer of BMI are available for anyone interested in the details of this phase of the project.

20. How were the various attractants--both natural and synthetic--tested for their relative attracting power?

They were tested in both the laboratory and the forest by use of olfactometers, and also in the forest by baiting trap trees.

In the forest tests, several olfactometers are used simultaneously. Separate traps are baited with the test materials, and one with a standard of 50 females in a log section. The traps are all turned on at the same time during an active beetle flight and run for a specified length of time. The beetles collected by the various traps are counted for comparison. The most attractive compounds attract the most beetles.

In the case of trap tree tests, several trees are baited with different materials to determine which attracts the most beetles.

21. What is the justification for this special cooperative research effort?

In 1967 the stumpage value of the estimated annual net (unsalvaged) loss of 150 million board feet was calculated to be at least $2,500,000, or about $17.00 per thousand board feet. This estimate of value loss is no doubt too low in view of today's stumpage prices.

The mountain pine beetle has also caused unappraised but heavy losses in several other species of pines in many of the 11 western states. The most important pine species attacked, in addition to white pine, are ponderosa, sugar and lodgepole.

The pine species infested by this insect form the base for a significant part of the forest products industry, not only in Idaho and the Northern Rocky Mt. Region, but in much of the West. Anything which threatens the health and efficient productivity of this industry is in turn a threat to thousands of employees and to the economic well-being of the dependent communities.

In addition to the outright loss of merchantable timber, the dead trees create a severe fire hazard in many areas, and other values of the forest--watershed, scenic and recreation--are also adversely affected.

The direct timber values at stake and direct and indirect economic and social values being threatened strongly warrant the pursuit of an aggressive, coordinated research program to try to find better ways of controlling this perennial forest pest.

22. How, when, and why was this research program organized?

The project grew out of action by the Montana-Northern Idaho Forest Pest Action Council, which is one of several such councils sponsored by the

Western Forestry and Conservation Association. The purpose of the councils is to appraise forest pest problems in their respective areas and to stimulate and coordinate action on needed research and control programs.

In February, 1965, the MNIFPAC appointed the White Pine Committee to seek and study new ideas for control of the mountain pine beetle which had been causing serious losses of several pine species, particularly white pine, over many years.

The reason for this action was a 1964 announcement by the Intermountain Forest and Range Experiment Station (U.S. Forest Service, Ogden, Utah) that it was deferring any further research on controlling the mountain pine beetle in white and ponderosa pines. Many forest managers felt this deferrment left a serious research gap which needed to be filled. Investigation by the W. P. Committee revealed that other sources of high-caliber research talent and funds were available. Hence, this cooperative project was initiated.

For more background on the development of the project, see "Review of Previous Efforts" in our committee's "Progress Report #4" of November 20, 1967.

23. How is the project financed?

Funds to underwrite this cooperative project have come from several sources, as indicated below:

Source	Amount by Years			
	1966	1967	1968	1969
	Approx.			
Boyce Thompson Institute(1)	$50,000	$77,000	$63,000	$32,000
Potlatch Forests, Inc.	5,000	15,000	12,000	22,000
Idaho Forest Management Fund(2)	none	20,000	25,000	25,000
Total	$55,000	$112,000	$100,000	$79,000

(1) Includes funds from the Boyce Thompson Institute and grants to the Institute from the U. S. Public Health Service, and the Margaret T. Biddle Foundation.

(2) A special account established by state law (Idaho Code 38-407 & 408) for cooperative forest pest abatement and control, which accumulates to a ceiling of $100,000 from 5% of monies collected by the State from timber harvest on private lands and State timber sales for logging slash disposal and fire hazard reduction. Disbursements from this fund must be approved by the Idaho State Land Board.

24. Why pheromones?

Since the early part of the present decade, the public's attention has been sharply focused on the hazards of environmental polution through the wide-spread use of pesticides. Miss Carson's "Silent Spring" dramatically publicized both real and unreal dangers of applying large quantities of insecticides to our pastures, crops, forests, and cities. The use of broad spectrum insecticides, such as DDT for example, poses a threat to bees when used on alfalfa, to fish when used near streams, and to humans when applied to their food.

One method in circumventing or reducing the risks associated with insecticides is to make the toxicant highly selective, i.e., so it only affects the target pest. Another method would be the development of a technique whereby highly toxic insecticides or other decimating agents could be used in such a manner that exposure of nontarget organisms would be eliminated or markedly reduced. Pheromones are somewhat specific to certain bark beetle species, therefore they would automatically become potential materials for developing the latter approach to control.

Bark beetle pheromones or attractants are highly potent and in minute quantities attract beetles over a large area. Considerable species specificity, at least within the genus, is indicated; however, cross attraction between species is known. The potency and specificity of these compounds support the theory that they can be used in conjunction with insecticides in an effective and safe control program.

25. What is the present status of the project?

The 1969 tests produced results which are highly encouraging. Actual control of the insect over large areas cannot yet be claimed, but the tests to date have conclusively demonstrated that large numbers of naturally-emerged, flying beetles can be attracted to baited white pines with few attacks occurring on unbaited pines in the treatment area. Therefore, the possibility of some degree of control through pest density regulation has been greatly enhanced. The major hurdle remaining is the development of a more simplified and sure method of exterminating attracted beetles. These conclusions are based on the following facts:

(1) Synthetic trans-verbenol at microgram levels plus alpha pinene is highly competitive with natural attractant sources.

(2) The attractant is not difficult to synthesize and high purity is not required for optimum activity.

(3) The physical properties of trans-verbenol and alpha pinene make possible simple and practical delivery systems such as small-bore polyethylene tubing.

(4) On the average, the synthetic pheromone attracts nearly equal numbers of male and female beetles.

(5) Large-scale testing of insect and host components of the attractant complex in a practical release system has been successfully completed.

(6) Although lindane killed an undetermined number of beetles, it was not completely effective in protecting baited trees.

In this light, trans-verbenol becomes an extension to the concepts of biological control.

For more information on 1969's tests and plans for 1970, write to R. G. Cox, P.O. Box 600, Lewiston, Idaho.